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ABSTRACT

This fifth in a series of ten modules for a course titled Welding Inspection describes qualification requirements for welding procedures and welders and the role of the nuclear quality assurance/quality control technician. The module follows a typical format that includes the following sections: (1) introduction, (2) module prerequisites, (3) objectives, (4) notes to instructor/student, (5) subject matter, (6) materials needed, (7) procedures, (8) data table, (9) reference materials, (10) test. (The course is one of fifteen technical courses for the second year of a two-year postsecondary curriculum in Nuclear Quality Assurance/Quality Control Technology.) (LRA)

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NUCLEAR TECHNOLOGY

COURSE 28 WELDING INSPECTION

MODULE 28-5 Qualifications

CE 024 265

GENERAL PHYSICS CORPORATION
Columbia , Maryland

COURSE MODULES

COURSE 28 WELDING INSPECTION

Module 28-1	Welding Fundamentals and Processes
Module 28-2	Shielded Metal Arc and Oxyacetylene Welding
Module 28-3	Tungsten Inert Gas (TIC), Metal Inert Gas (MIG) and Submerged Arc Welding
Module 28-4	Weld Joint Verification
Module 28-5	Qualifications
Module 28-6	Process Controls
Module 28-7	Acceptance Inspection
Module 28-8	Filler Metal Control
Module 28-9	Weld Repair Control
Module 28-10	Records

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This module was prepared for General Physics Corporation by John Espy, General Physics Corporation.

GENERAL PHYSICS CORPORATION

1979

INTRODUCTION

The welding engineer is responsible for the preparation and qualification of welding procedures. Either the welding engineer or the welding department manager is responsible for qualifying welders. The QA/QC Technician is responsible for monitoring these qualifications to assure compliance with governing welding codes. In addition, the QA/QC Technician monitors production welding to determine that qualified procedures and welders are used.

Prior to any welding taking place, the welding procedure and the welder are required to be qualified by governing welding codes. While welds are nondestructively examined for welding defects, the total quality of the weld cannot be determined solely by nondestructive examination. Destructive tests, such as tensile and bend tests, are required to determine the mechanical properties of the weld (strength, ductility, toughness). Because production welds cannot be destructively tested, their mechanical properties can be ascertained by qualifying the welding procedure and the welder and by ensuring compliance with the qualified procedure during production welding.

This module describes qualification requirements for welding procedures and welders and the role of the Nuclear QA/QC Technician. The module includes discussion of applicable codes and methods of qualification stipulated therein. It describes administrative controls for training from a welded joint to the procedure and welder qualification records. It describes the destructive and nondestructive testing which determines acceptability of qualification. It describes requirements for requalification of welding procedures and welders.

MODULE PREREQUISITES

Modules 28-1 through 28-4 shall be completed before beginning this module.

OBJECTIVES

Upon completion of this module, the student/trainee can:

1. Describe the general responsibilities of the QA/QC Technician with respect to welding qualifications.
2. Match any of the three welding codes to their applications.
3. Describe the general method for qualifying welding procedures and welders.
4. State the purposes of the following documents:
   a. welding procedure specification
   b. procedure qualification record
   c. welder qualification record
5. Describe the administrative controls that permit tracing from a welded joint to the welding procedure, and the welder and the qualification records of each.
6. State the rationale for given requirements pertaining to the welding of a qualification test piece.
7. Demonstrate the ability to determine qualification requirements for a given welding procedure or welder and applicable welding code.
8. Name three types of mechanical tests used in welding procedure qualifications and state the purpose for each test.

9. Describe the condition to be met for a bend test specimen to be categorized as side bend, face bend and root bend.
10. Determine for stated changes to welding procedures or welder's assignments if requalification is required, given a welding code or set of essential variables governing qualification requirements.

CODES AND STANDARDS

General

Qualification criteria are set forth by the code or standard that governs the welding of components, systems, or structures. For nuclear power plants, one of three welding codes apply to practically all welding. These codes are: (1) ASME Boiler and Pressure Vessel Code, (2) AWS Structural Welding Code, and (3) AWS Reinforcing Steel Welding Code.

ASME Boiler and Pressure Vessel Code

The American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code is applied to welding of nuclear power plant items classified as "safety related". The definition of "safety related" is:

> Those plant features necessary to assure the integrity of the primary coolant pressure boundary, the capability to shut down the reactor and maintain it in a safe shut down condition, or the capability to prevent or mitigate the consequences of accidents which could result in off site exposures comparable to the guideline exposure of Title 10, Code of Federal Regulations, Part 100, "Reactor Site Criteria".

From this definition, one can generalize that the ASME Boiler and Pressure Vessel Code applies to reactor systems, reactor and containment safety systems, and safety related appurtenances such as supports, hangers, brackets and foundations. Section IX of the ASME Boiler and Pressure Vessel Code specifies the qualification requirements pertaining to welding procedures and welders under this code. This code requires successful completion of specific tests of

welded specimens as the prerequisite for qualification of both procedures and welders.

AWS Structural Welding Code

The American Welding Society (AWS) Structural Welding Code D1.1 describes welding requirements that could be applied to any type of welded structure. Designers of nuclear power plants often invoke this code for welding of structures that are not classified as safety related. Section 5 of this code stipulates the qualification requirements. It permits declaring a welding procedure as being prequalified if the procedure meets the requirements and limitations of this code. If not or if requested by the purchaser, the welding procedure qualification is based on satisfactory completion of specified tests on welded specimens. For welders, this code requires satisfactory completion of specified tests on welded specimens for certification of qualification.

AWS Reinforcing Steel Welding Code

The AWS Reinforcing Steel Welding Code, D12.1 describes the welding requirments applicable to the welding of reinforcements in concrete structures. This code is referenced by concrete standards issued by the American Concrete Institute as an acceptable code for welding of reinforcements in concrete structures. Section 6 of this code specifies qualification requirements for both welding procedures and welders. In both cases, qualification is based on the satisfactory completion of specific tests on weld test specimens.

QUALIFICATION TECHNIQUES

Overview

Welding procedures are qualified in order to demonstrate that the procedure will produce a weld that meets the requirements specified by the designer. Such requirements typically pertain to strength aspects but sometimes include the weld's resistance to corrosion. Welders are qualified in order to demonstrate that the individual, when using a qualifed procedure, can make a sound weld.

The welding engineer is normally responsible for preparation of welding procedures and the instructions for qualifying both procedures and the welders. The QA/QC Technician monitors the qualifications to assure compliance with the applicable welding codes.

The qualification method is the welding of a qualification test piece (or coupon) in accordance with a welding procedure specification and subjecting the welded piece to tests that determine the quality of the weld. The governing welding code stipulates requirements pertaining to the test piece (such as material, thickness, and position) and requirements pertaining to the tests (such as type, number, location of test specimen, testing techniques, and acceptance criteria). This module generally describes the requirements of the ASME Boiler and Pressure Vessel Code since it is the more stringent of the welding codes and it encompasses the requirements of the other codes.

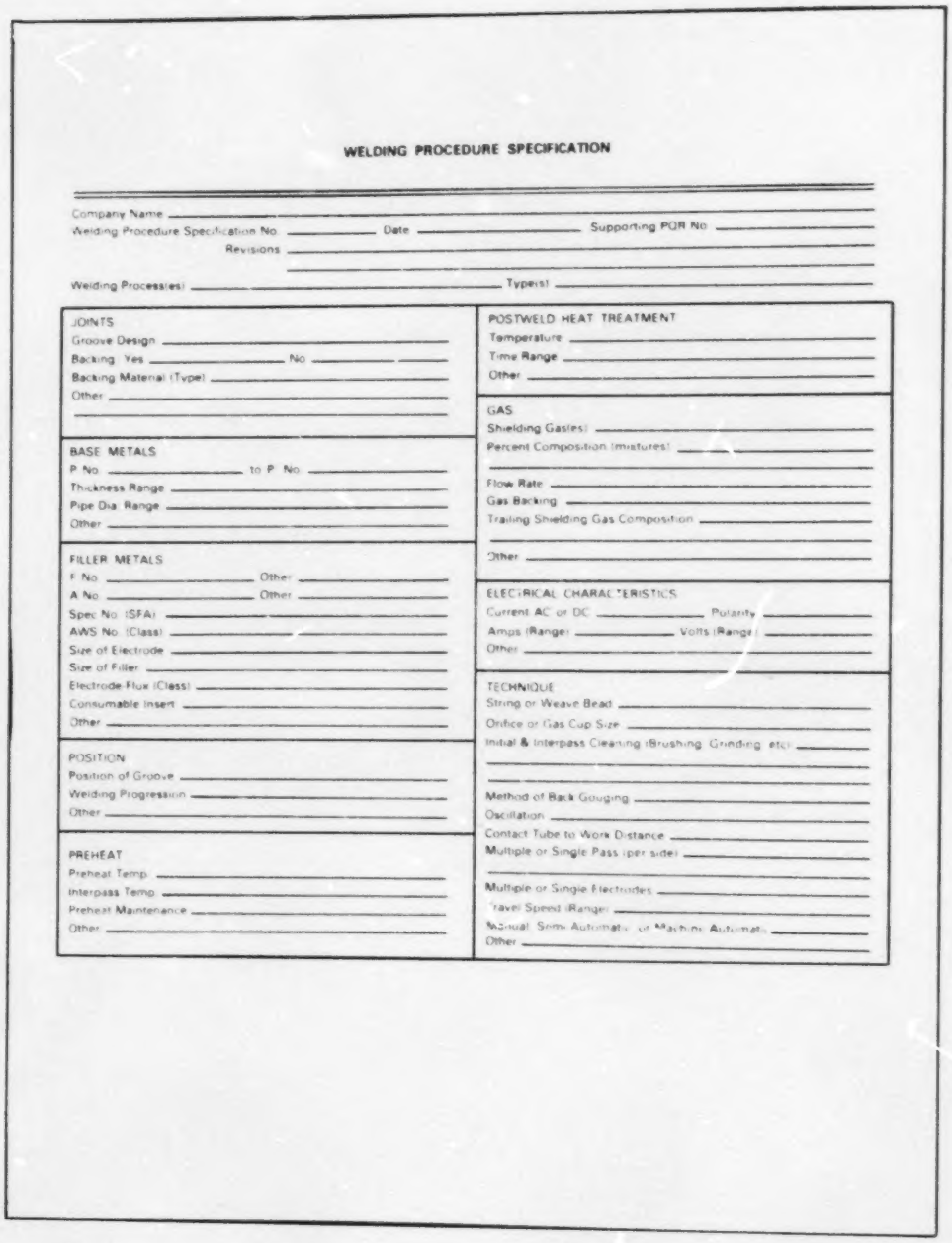
Welding Procedure Specification

The welding procedure specification provides the welder with the necessary direction to weld in accordance with the welding code. It is available to the welder at the welding station. It may or may not be supplemented by a more detailed welding procedure dependent on local circumstances. Such supplementary welding procedures must be consistent with the welding procedure specification.

The welding procedure specification details the instructions and parameters to be followed by the welder for all essential and nonessential variables applicable to the welding process. Essential variables are those which require requalification when changed beyond limits. Nonessential variables are those that can be changed without requalification.

Each welding procedure specification must be supported by qualification tests. A typical format for welding procedure specification is given in Figure 28-5-1.

Space for two key identifying numbers is provided at the top of the form illustrated in Figure 28-5-1. In the upper left hand corner, the welding procedure specification number is recorded. In the upper right hand corner, the serial number of the supporting procedure qualification record is recorded. These two numbers are assigned by the organization responsible for welding and each is unique in that it is never used more than once. Therefore, reference to the first number permits retrieval of the welding procedure specification which in turn references the record that contains the correspondence qualification test results. All other records and procedures pertaining to welding operations reference the welding procedure specification number. For example, an installation record would identify the number of the welding procedure specification that



WELDING PROCEDURE SPECIFICATION

Company Name _____

Welding Procedure Specification No. _____ Date _____ Supporting PQR No. _____

Revisions _____

Welding Process(es) _____ Type(s) _____

JOINTS
Groove Design _____
Backing Yes _____ No _____
Backing Material (Type) _____
Other _____

BASE METALS
P No. _____ to P No. _____
Thickness Range _____
Pipe Dia Range _____
Other _____

FILLER METALS
F No. _____ Other _____
A No. _____ Other _____
Spec No. (SFA) _____
AWS No. (Class) _____
Size of Electrode _____
Size of Filler _____
Electrode-Flux (Class) _____
Consumable Insert _____
Other _____

POSITION
Position of Groove _____
Welding Progression _____
Other _____

PREHEAT
Preheat Temp. _____
Interpass Temp. _____
Preheat Maintenance _____
Other _____

POSTWELD HEAT TREATMENT
Temperature _____
Time Range _____
Other _____

GAS
Shielding Gas(es) _____
Percent Composition (mixtures) _____
Flow Rate _____
Gas Backing _____
Trailing Shielding Gas Composition _____
Other _____

ELECTRICAL CHARACTERISTICS
Current AC or DC _____ Polarity _____
Amps (Range) _____ Volts (Range) _____
Other _____

TECHNIQUE
String or Weave Bead _____
Orifice or Gas Cup Size _____
Initial & Interpass Cleaning (Brushing, Grinding, etc.) _____
Method of Back Gouging _____
Oscillation _____
Contact Tube to Work Distance _____
Multiple or Single Pass (per side) _____
Multiple or Single Electrodes _____
Travel Speed (Range) _____
Manual, Semi-Automatic or Machine Automatic _____
Other _____

Figure 28-5-1 Typical Format of Welding Procedure Specification

governed the installation welding. Similarly, nondestructive test records would identify the welding procedure specification number. In this manner, a cross reference is maintained to the records that prove the qualification of the welding procedure qualification.

Procedure Qualification Record

When the welding procedure specification is qualified, a record of the qualification tests is made to provide objective evidence at any future time of the qualification. This procedure qualification record is uniquely serialized as previously discussed and is centrally filed to permit convenient access at any time. A typical format for the procedure qualification record is given in Figure 28-5-2.

As illustrated in Figure 28-5-2, space is provided at the top of the procedure qualification record to identify the record number and the welding procedure specification number. Again, the cross reference between these documents is maintained.

Entries recorded on the procedure qualification record reflect the actual practices employed in welding and testing the qualification test piece. The QA/QC Technician is typically responsible for making these entries or reviewing the record for completeness and acceptability of the entries.

As discussed later in this module, a single procedure qualification record can support the qualification of more than one welding procedure specification. For example, if two welding procedure specifications contain identical essential elements but different nonessential elements, one qualification test piece and corresponding procedure qualification record would support the qualification of both. In this example, the same welding process must have been used in both cases because the welding process is always considered an essential element.

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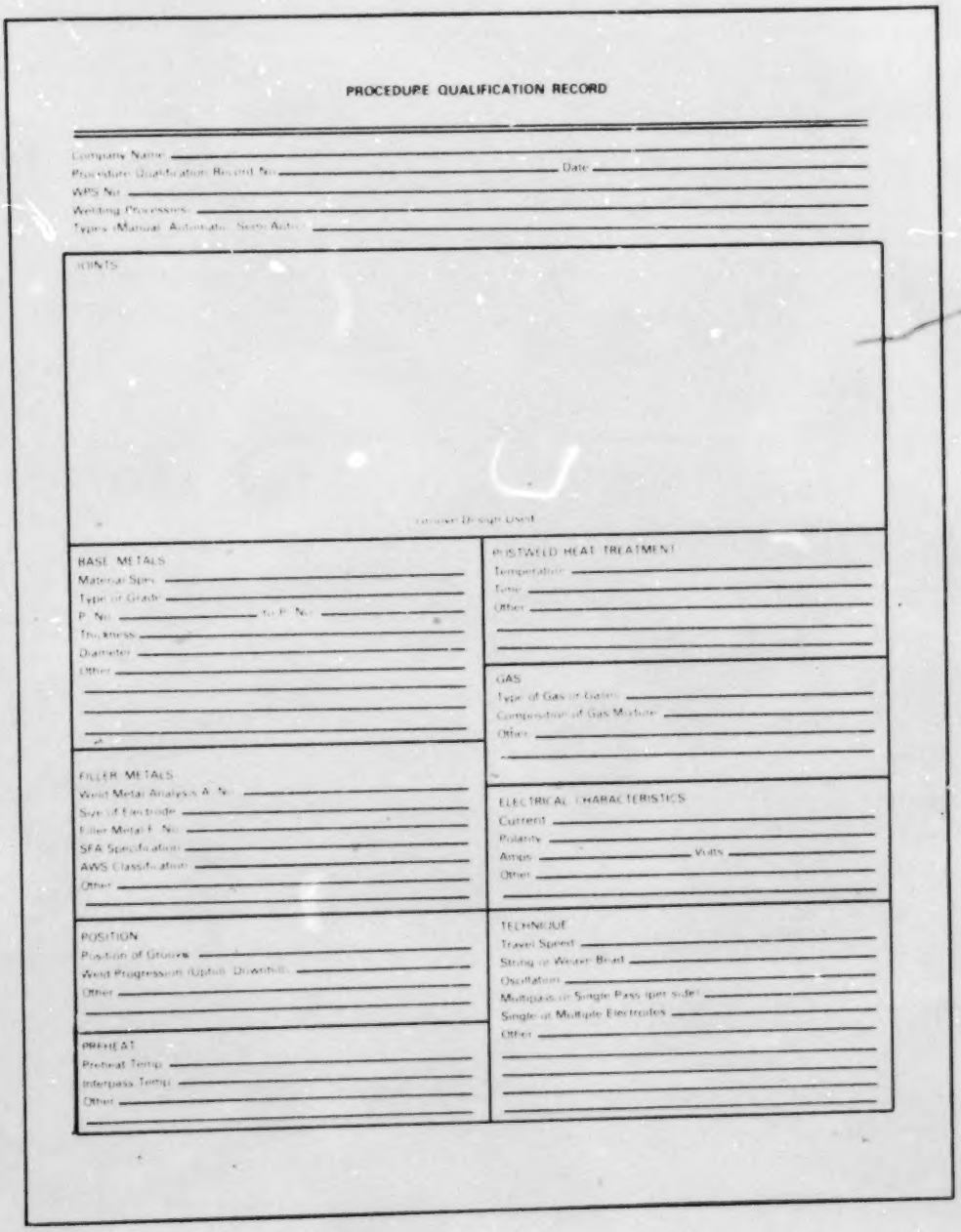

PROCEDUPE QUALIFICATION RECORD

Company Name
Procedure Qualification Record No. Date
WPS No.
Welding Processes
Types (Manual, Automatic, Semi-Auto.)

JOINTS

Groove Design Used

BASE METALS
Material Spec.
Type or Grade
P. No. to P. No.
Thickness
Diameter
Other

FILLER METALS
Weld Metal Analysis A. No.
Size of Electrode
Filler Metal F. No.
SFA Specification
AWS Classification
Other

POSITION
Position of Groove
Weld Progression (Uphill, Downhill)
Other

PREHEAT
Preheat Temp.
Interpass Temp.
Other

POSTWELD HEAT TREATMENT
Temperature
Time
Other

GAS
Type of Gas or Gases
Composition of Gas Mixture
Other

ELECTRICAL CHARACTERISTICS
Current
Polarity
Amps. Volts
Other

TECHNIQUE
Travel Speed
String or Weave Bead
Oscillation
Multipass or Single Pass (per side)
Single or Multiple Electrodes
Other

Figure 28-5-2a Sample Format for Procedure Qualification Record

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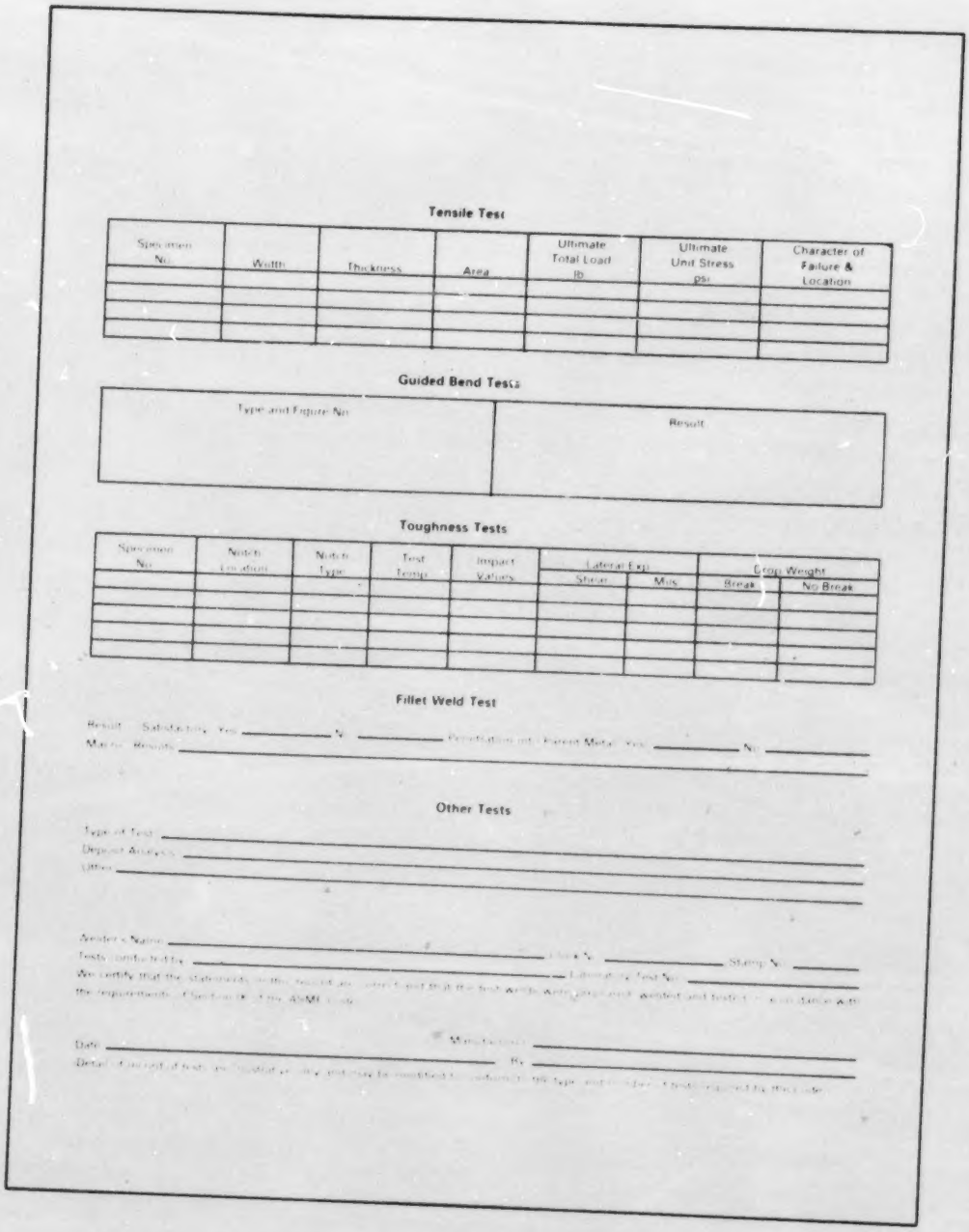


Tensile Test

Specimen No.	Width	Thickness	Area	Ultimate Total Load lb	Ultimate Unit Stress psi	Character of Failure & Location

Guided Bend Tests

Type and Figure No.	Result

Toughness Tests

Specimen No.	Notch Location	Notch Type	Test Temp.	Impact Values	Lateral Exp.		Drop Weight	
					Shear	Mils	Break	No Break

Fillet Weld Test

Result — Satisfactory: Yes _____ No _____ Penetration into Parent Metal: Yes _____ No _____

Macro: Results _____

Other Tests

Type of Test: _____

Deposit Analysis: _____

Other: _____

Welder's Name _____ Clock No. _____ Stamp No. _____

Tests conducted by: _____ Laboratory Test No. _____

We certify that the statements in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

Manufacturer _____

Date _____ By _____

Detail of record of tests of welding procedure qualification to be welded. Identify the type and grade of material welded (Group No.).

Figure 28-5-2b Sample Format for Procedure Qualification Record

Welder Qualification Record

The welder qualification record gives objective evidence that a welder is qualified. (For this course, welder is used to mean both a welder and a welding operator. Most welding codes define a welder as one who is capable of performing a manual or semi-automatic welding operation. The codes define welding operator as one who operates machine or automatic welding equipment. For code requirements that do not apply equally to a welder and a welding operator, the more stringent requirements apply to the welder.) The individual who welds the welding procedure specification qualification test piece becomes qualified if the procedure is qualified. Each additional welder who will use the same welding procedure specification, makes additional test pieces. On a large job, 100 or more welders could be qualified for a given welding procedure specification. Also, as described later in this module, the welder qualification on one procedure can be valid for many other procedures. Accordingly, the easiest administrative system for keeping track of who is qualified for what is by a log book or computerized listing. The log lists for each welding procedure specification serial number, the names or stamp numbers for all welders qualified for that procedure. Individual welder qualification records are filed by name or stamp number and can be reviewed to confirm the accuracy of the log.

Qualification Test Piece (Coupon)

The governing welding code specifies the requirements for welding the qualification test piece. These requirements have the objective of producing a test piece that is directly representative of the weld that would be produced when the welding procedure specification is used in the

MANUFACTURER'S RECORD OF WELDER OR WELDING OPERATOR QUALIFICATION TESTS

Welder Name _____ Check No _____ Stamp No _____
Welding Process _____ Type _____
In accordance with Welding Procedure Specification (WPS) _____
Backing _____
Material Spec _____ to _____ of P No _____ to P No _____
Thickness _____ Dia _____
Filler Metal Spec No _____ Class No _____ F No _____
Other _____
Position (1G, 4F, 6G, etc.) _____
Gas Type _____ % Composition _____
Electrical Characteristics Current _____ Polarity _____
Weld Progression _____
Other _____

For Information Only

Filler Metal Diameter and Trade Name _____
Submerged Arc Flux Trade Name _____
Gas Metal Arc Welding Shield Gas Trade Name _____

Guided Bend Test Results

Type and Fig. No.	Result

Radiographic Test Results

For alternative qualification of groove welds by radiography

Radiographic Results _____

Fillet Weld Test Results

Fracture Test (Describe the location, nature and size of any crack or tearing of the specimen) _____
_____
Length and Per Cent of Defects _____ inches _____ %
Macro Test Fusion _____
Appearance Fillet Size (leg) _____ in. X _____ in. Convexity _____ in. or Concavity _____ in.

Test Conducted by _____ Laboratory Test No _____
We certify that the statements in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of Sections IX of the ASME Code.

Organization _____
Date _____ By _____

(Detail of record of tests are illustrative only and may be modified to conform to the type and number of tests required by the Code.)
NOTE: Any essential variables in addition to those above shall be recorded.

Figure 28-5-3 Typical Format for Welder Qualification Record

shop or field. If this representative weld passes the qualification tests, it is logical to assume that satisfactory shop and field welds will result from use of the welding procedure specification.

Requirements for the qualification test piece typically encompass joint design, material type, base material thickness, and heat treatment. These are generally as follows:

- Joint Design - Joint design (excluding thickness) is not an essential variable for welding procedure specification qualification for OA, SMA, TIG, MIG and SAW. This is because these welding processes are adaptable to all types of joints. The typical requirement is only that the type of joint specified in the procedure is used in the qualification test piece. For example, if the procedure calls for a double U groove, the test piece should have a double U groove weld preparation. However, the use of backing in a joint does influence the techniques used by welders. Therefore, for welder performance qualification, backing must be used with the qualification test piece if backing is specified in the welding procedure specification.
- Material Type - The material type for both base materials and filler materials directly influence weldability and resultant strength of the weld. For this reason, the qualification test piece and filler materials used in the procedure and the welder performance qualification must be of the same "family" of material as specified by the welding procedure specification. Family of materials refers to groupings of similar materials made by all welding codes. Such groupings consider the weldability and chemical similarity of materials and avoid unneces-

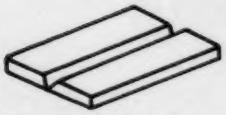
sary numbers of qualification test pieces. For example, any of the materials listed in Table 28-5-1 qualifies the other materials under the same "P" number. (Table 28-5-1 is a partial listing taken from ASME Boiler and Pressure Vessel Code.)

- Base Material Thickness - As thickness of a weld joint increases, it becomes somewhat more difficult to make a quality weld. As thickness increases, more passes are necessary with attendant increases in the number of meltings and resolidifications. Also, the larger mass of surrounding material tends to increase the thermal gradient. These factors increase susceptability to cracking and other weld defects. Therefore, welding codes typically require the qualification test piece to be essentially as thick as the material to be welded in the shop or field. For example, the ASME Boiler and Pressure Vessel Code specifies three types of conditions for thickness of the qualification test piece. For the various condition, the qualification test piece must be either 50%, 90% or 100% of the weld joint material thickness.
- Position - The OA, SMA, TIG, and MIG welding processes are so adaptable to all positions that position of the qualification test piece is of little importance to procedure qualification. For this reason, position of the qualification test piece is not specified except for welds that require impact testing as part of the qualification. In such cases, vertical position with uphill progression requires separate qualification. However, position greatly influences the techniques employed by a welder. Therefore, the position used during qualification must be equivalent to the position that the welder will use in the shop or field.

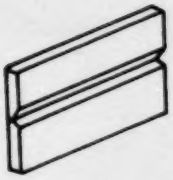
Table 28-5-1

Grouping of Base Metals for Qualification		
P No.	Base Metal Specification	Nominal Composition
1	SA-283	Carbon Steel Plate
1	SA-675	Carbon Steel Bar
1	SA-524	Carbon Steel Pipe
3	SA-533	Low Alloy Plate
3	SA-541	Low Alloy Forgings
8	SA-240	Austenitic Stainless Steel Plate
8	SA-249	Austenitic Stainless Steel Tubes
8	SA-336	Austenitic Stainless Steel Forgings
43	SB-163	Ni-Cr-Fe Condenser Tubes
43	SB-166	Ni-Cr-Fe Rod, Bar
43	SB-167	Ni-Cr-Fe Pipe, Tube

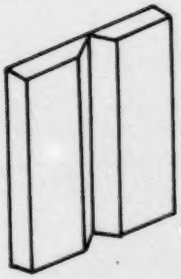
Equivalency of position is based on the degree of difficulty in making the weld. More difficult positions qualify the welder not only for the position used for the qualification test piece but also for the less difficult positions. Figure 28-5-4 illustrates the positions for pipe and plate given by ASME Boiler and Pressure Vessel Code.



a. 1G, Flat

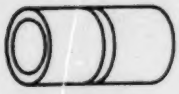


b. 2G, Horizontal



c. 3G, Vertical

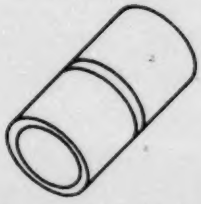
d. 4G, Overhead



a. 1G, Rotated Flat

b. 2G, Horizontal

c. 5G, Flat, Vertical and Overhead



d. 6G, All

Figure 28-5-4 Test Positions for Groove Welds in Pipe

As shown in Figure 28-5-4, the test positions for groove welds become progressively more difficult with increasing position identification code numbers. In visualizing a welder making a weld around the stationary pipe in position 6G, one can see that all positions are represented. If it is expected that a welder would be required to weld in all positions, position 6G would be used for the qualification test piece. If a welder could not qualify in position 6G but could quality in position 2G, the welder would be assigned only flat and horizontal welding. Table 28-5-2 gives representative limits of groove welding qualification based on welding pipe in the positions shown in Figure 28-5-4.

Table 28-5-2

Welder Performance Qualification Limits for Groove Welds		
Position of Test Pipe	Positions Qualified	
	Plate	Pipe
1G	1G	1G
2G	1G, 2G	1G, 2G
5G	1G, 3G, 4G	1G, 5G
6G	All	All

- Heat Treatment - There are three types of temperature controls associated with welding: preheat, interpass and post weld heat treatment temperatures. Of these three, preheat and interpass temperatures are controlled specifically to prevent welding defects. If either of these controls are not used during qualification welding, the probability of failure increases. Therefore, welding codes normally do not require

maintaining preheat and interpass temperatures during welding of the qualification test piece. Nonetheless, most companies have the policy to control these temperatures during qualification welding specified in the welding procedure specification in order to instill the practice of procedural compliance.

Post weld heat treatment has the purpose of obtaining the desired metallurgical properties in the weld. Therefore, for qualification of welding procedure specifications, welding codes require the welded test piece to be subjected to the same post weld heat treatment as specified for the shop or field weld. Tests performed on the test piece are done after heat treatment. For welder qualifications, welding codes typically permit (but not require) post weld heat treatment of the qualification test piece when post weld heat treatment is specified by the welding procedure specifications. As with preheat and interpass temperatures, such permissiveness is based on the increased probability of failure if post weld heat treatment is not used.

QUALIFICATION TESTS

Test Piece

The governing welding code specifies the required tests and the acceptance criteria for each test for qualification of both welding procedure specifications and welders. In general, one qualification test piece supplies all necessary test specimens. In certain applications, however, more than on qualification test piece is required. For examples, qualification of tube-to-tubesheet welds uses a mockup consisting of ten welds, automatic seal welding requires six consecutively welded test pieces, and manual seal welding

requires two test pieces. Thus, each application requires research of the governing welding code to determine the required number of test pieces to be welded.

Mechanical Tests

Qualification of welding procedure specifications involve three mechanical tests: tension, bend, and impact. Tension and bend tests are normally required by welding codes for each qualification. Impact tests are required only in applications where notch toughness is important to the function of the welded item. For example, reactor pressure vessel welds are subjected to impact tests during qualification because of the need to insure that brittle fracture will not occur during reactor startup and operation. Typical numbers of tension and bend tests per qualification test piece are shown in Table 28-5-3 for procedure qualification and Table 28-5-4 for welder qualification.

Impact tests are required for procedure qualification whenever the base material specification applicable to the metals to be joined by welding require impact testing. When applicable, three impact test specimens are normally required. Two specimens are removed from the test piece such that they represent the weld metal. The other specimen is cut from the heat affected zone.

Typical locations from which tension and bend test specimens are cut are illustrated in Figure 28-5-5.

Mechanical tests determine the strength of the weld. In general, the weld must be as strong as the base metal as determined by the mechanical tests. Specific requirements are given by the applicable welding code.

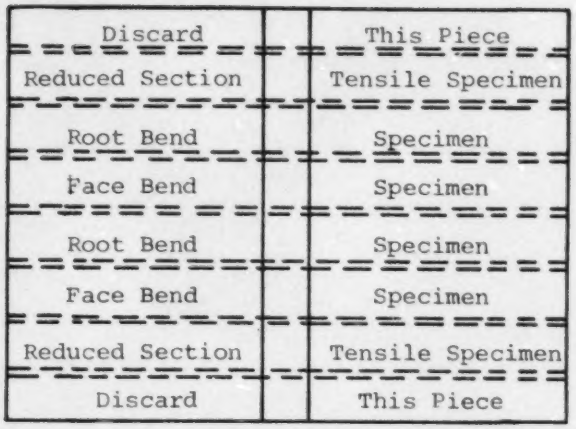
Tension tests determine the ultimate strength of the welds. Dependent on the test piece thickness, and the requirements of the governing welding code, the tension test specimen may be full thickness or reduced thickness

Table 28-5-3

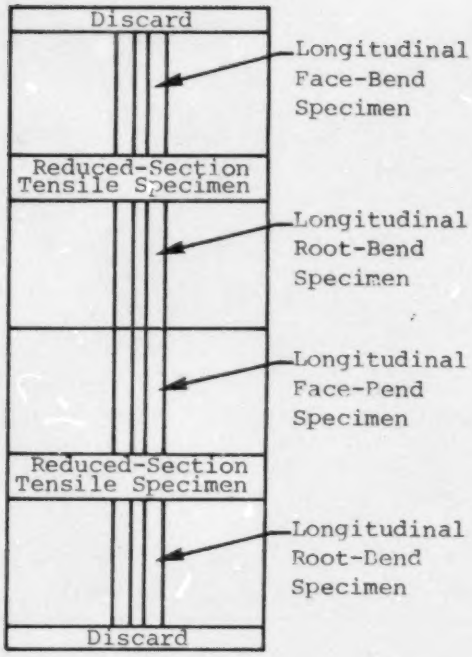
Procedure Qualification Mechanical Tests (Typical)						
Thickness, t, of Test Piece	Material Thickness Qualified		Number and Type of Tests			
			Tension	Transverse Bend		
	Min.	Max.		Side	Face	Root
< 1/16 inch	t	2t	2		2	2
1/16 - 3/8 inch	1/16	2t	2		2	2
> 3/8 < 3/4 inch	3/16	2t	2		2	2
> 3/4 inch	3/16	2t	2	4		

Table 28-5-4

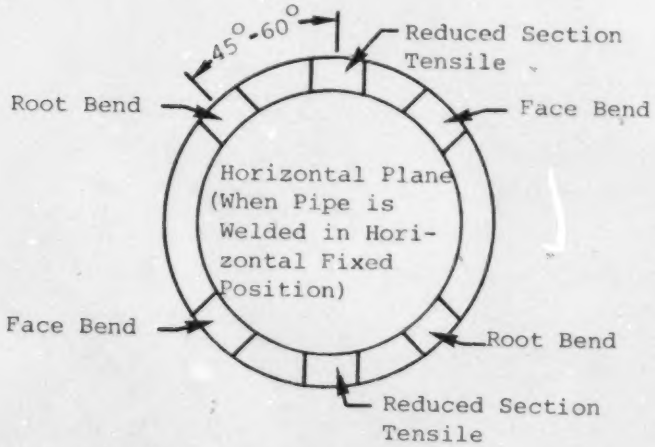
Welder Qualification Mechanical Tests (Typical)					
Thickness, t, of Test Piece	Material Thickness Qualified		Number and Type of Tests Transverse Bend Tests		
	Min.	Max.	Side	Face	Root
1/16 - 3/8 inch	1/16	2t		1	1
> 3/8, < 3/4 inch	3/16	2t		1	1
3/4 inch and over	3/16	t	2		



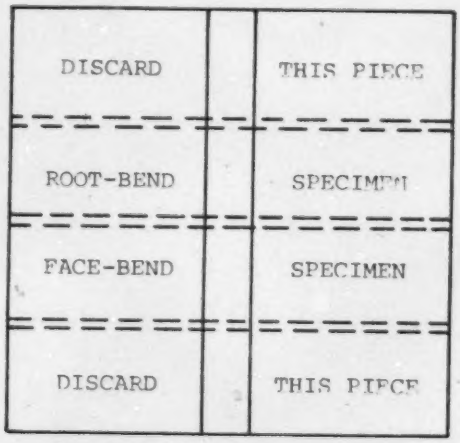
(a) Procedure Qualification, Transverse Test Specimens in Plate



(b) Procedure Qualification Longitudinal Test Specimens in Plate



(c) Procedure Qualification, Test Specimens in Pipe



(d) Welder Qualification, Test Specimens in Plate

Figure 28-5-5 Typical Location of Test Specimens

specimens. Tension tests are required for procedure qualification but not for welder qualification. This is because improper welder techniques would be revealed by other tests and the ultimate strength of the weld will not vary substantially if the procedure is not changed. Typical acceptance criteria found in the governing welding code are as follows for the tension tests:

- minimum tensile strength equal to or greater than that of the base metal.
- minimum tensile strength equal to or greater than the weaker base material for test pieces representing the joining of base metals of different strength.
- tensile specimen breaking in the base metal and outside of the fusion line provided the strength is not more than 5% less than the specified minimum tensile strength of the base metal.

Bend tests determine the soundness (lack of welding defects) and the ductility of the weld. Normally, transverse bend tests are performed, i.e., the weld is transverse to the longitudinal axis of the test specimen. However, when bending properties differ markedly between either the two base metals or the weld metal and base metal, longitudinal tests may be performed. The longitudinal bend test specimen has the weld metal parallel to the longitudinal bend test specimen (i.e., the specimen consists of weld metal, fusion zone, and heat affected zone). Regardless of whether transverse or longitudinal bend tests are performed, the weld metal and heat affected zone must lie completely within the bent portion of the specimen after testing. Acceptance criteria consist of limits on visually discernable openings in the convex surface of the bent specimen. A typical limit is no open defect exceeding 1/8 inch as measured in any direction. Such limits apply to each of the three bend test methods.

Bend test specimens are prepared by cutting the test piece to form specimens of rectangular cross section. For side bend tests, the specimen is cut transverse to the weld such that a transverse cross-section of the weld is tested. For face and root bend tests, the specimen is cut transverse or longitudinal to the weld, whichever is specified. In either instance, face bend tests require the weld face to become the convex surface after testing. Similarly, the root becomes the convex surface after root bend testing.

Impact tests determine the notch toughness of the weld. When impact testing is required, test specimens are removed from the weld metal and the heat affected zone at a depth of 1/4 t or more where t equals base metal thickness. Each specimen is tested at a temperature that is equal to or lower than the lowest service temperature specified for the welds. Acceptance criteria consist of limits on absorbed energy and dimension of lateral expansion of the broken specimen.

Special Tests

In nuclear power plant welding, certain welds are specially designed for unique purposes. In such cases, special tests are performed to qualify the procedure and welder. These special welds are (1) tube-to-tubesheet welds, (2) hardsurfacing, and (3) weld deposited cladding.

Tube-to-tubesheet welds are formed in steam generators and in certain other heat exchangers. Manufacturers of these components are normally responsible for these welds. Access for nondestructive examinations is severely limited due to the close proximity of thousands of tubes in the tubesheet. Qualification of the welding procedure and welder is based on welding a number of tube test pieces followed by liquid penetrant examination and sectioning of

the welds. The sectioned specimens are polished and visually examined for cracks at high magnification.

Hardsurfacing by welding is employed on a number of components having moving surfaces in contact during service. Qualification of the welding procedure and welder is based on welding a test piece that is subjected to liquid penetrant examination, sectioning, hardness testing, and chemical analysis. The sectioned test specimen is polished and visually examined at magnification for cracks in the bond line. The hardness test determines that the desired wear properties have been obtained. The chemistry test determines that little diffusion of base metal into the hardsurface deposit has occurred.

Weld deposited overlay cladding is employed for many components to provide a surface that is corrosion resistant. For example, the inside surfaces of a low alloy steel reactor pressure vessel is clad with stainless steel or nickel-chrome-iron alloys to give excellent resistance to corrosion. Qualification of these welding procedures and welders is based on depositing cladding on a flat block which is subjected to liquid penetrant examination and side bend tests.

Substitution of Radiography for Mechanical Tests

For qualification of welders (not procedures), welding codes permit deleting mechanical tests and substitution of radiographic examination in certain cases. For example, the ASME Boiler and Pressure Vessel Code generally permits substitution of radiography for mechanical tests for the qualification of welders for all types of carbon steel and low alloy steel base metals. When this option is employed, the qualification test piece is radiographed and the radiograph is viewed for indication of welding defects. Also, in lieu of a test piece, the welder's first production piece can be radiographed to determine qualification. Typical

acceptance criteria are (1) no indication of a crack, (2) no slag in excess of (length) (typically between 1/8 and 3/4 inch dependent on base material thickness), and (3) no more than (number) of rounded indications and no rounded indication larger than (size).

REQUALIFICATION

General

Once the welding procedure specification is qualified, it need not be requalified unless essential variables of the procedure are changed. Welders, however, need to periodically demonstrate their proficiency in welding. Such demonstration may be by performance of welding on the job. Therefore, formal requalification of welders is required only when the welder has not used the particular welding process for a considerable time period or when there is specific reason to question the welder's ability to make a sound weld.

Essential Variables for Procedure Qualification

The initial qualification of a welding procedure specification is valid until such time as essential variables are changed. Such changes give different weld properties in the final weld. Such changes may be to a given procedure or may be considered in a new procedure. When a new procedure is prepared it is compared with similar, existing, qualified procedures. If the new procedure contains values for essential variables that are within the range of those qualified, the new procedure is considered as qualified. In such event, the supporting Procedure Qualification Record serial number is entered on the new procedure. If a revised procedure or a new procedure

contain values for essential variables outside the range of those qualified, a new qualification is performed.

The governing welding code specifies for each welding process the applicable essential variables and the range of values beyond which requalification is required. The welding engineer is normally responsible for determining when requalification is required and for preparing the instructions for carrying out the requalification. The QA/QC Technician is normally responsible for monitoring the requalification effort to assure compliance with the welding code.

Typical changes to essential variables for OA, SMA, TIG, MIG and SAW welding processes that require requalification of the procedure are given in Table 28-5-5.

Essential Variables for Welder Qualification

For each welder qualification, the welder must periodically use the welding process or be requalified. Use of the process at least once per each six month period "maintains" the welder's qualification. Less frequent use requires requalification.

A welder who is qualified for a given welding procedure is considered qualified for all other welding procedures which employ the same welding process provided that essential variables do not differ beyond limits. Typical limits for essential variables for welder qualification are given in Table 28-5-6.

ADMINISTRATIVE CONTROLS

Purpose

Welding codes require certain administrative controls to permit review of qualification status at any time. These

Table 28-5-5

Change in Essential Variables Affecting Procedure Qualification					
Change to Essential Variable	Welding Process				
	OA	SMA	TIG	MIG	SAW
Base Metals					
- change in base metal types	X	X	X	X	X
- increase in base metal thickness beyond that qualified	X	X	X	X	X
Filler Materials					
- change in filler material type	X	X	X	X	X
- change in chemical composition of weld deposit	X	X	X	X	X
- change in flux classification					X
- addition or deletion of consumable inserts			X		
- deletion or addition of filler material			X		
- change in consumable electrode from bare to flux cored, flux covered or vice versa				X	
- addition, deletion or increase in amount of supplementary powdered filler material					X
Position					
- when impact test is required, a change from any position to the vertical uphill progression		X	X	X	
Preheat					
- a decrease of more than 100°F in specified preheat		X	X	X	X
Post Weld Heat Treatment					
- a change in temperature range	X	X	X	X	X
- for austenitic stainless steel, the addition or deletion of a solution or stabilizing heat treatment		X	X	X	X
- when lower critical temperature is exceeded, an increase in base metal thickness beyond 1.1 times the thickness of the qualified test coupon		X	X	X	X

Table 28-5-5 (Continued)

Change in Essential Variables Affecting Procedure Qualification					
Change to Essential Variable	OA	SMA	TIG	MIG	SAW
Gas					
- a change in the type of fuel gas	X				
- a change in type of gas or to a mixture, or change in percentage of mixture			X	X	
Electrical Characteristics					
- when impact testing is required, a change in type or polarity of current or an increase in voltage or amperage		X	X	X	X
Technique					
- when impact testing is required:					
- a change in pulsing frequency duration			X	X	X
- a change in arc timing of more than ± 10%			X	X	X
- a change in amperage of more than ± 10%			X	X	X
- a change from upward to downward or vice versa for the vertical position		X	X	X	
- for thickness less than 1 1/2 inches, an increase in volume of weld metal deposited beyond that qualified		X	X	X	X

Table 28-5-6

Change in Essential Variables Affecting Welder Qualification					
Change to Essential Variable	OA	SMA	TIG	MIG	SAW
Joint					
- deletion of backing ring in single welded butt joints		X	X	X	
- addition of backing	X				
Base Metal					
- a change in base metal thickness beyond the range qualified	X	X	X	X	X
Filler Material					
- a change in type of filler material	X	X	X	X	
- addition or deletion of consumable inserts					
Position					
- addition of a position other than that qualified for	X	X	X	X	X
Gas					
- a change in type of fuel gas	X				
- deletion of gas backing			X	X	
Electrical Characteristics					
- a change from spray arc, globular arc, or pulsating arc to short circuiting arc or vice versa				X	
- a change from AC to DC or vice versa; a change from straight polarity to reversed polarity or vice versa			X		
Techniques					
- a change from upward to downward progression or vice versa for the vertical position				X	

controls pertain to transfer of qualifications, identification of welding procedure to each weld joint and identification of welders to each weld joint.

Transfer of Qualification

Most welding codes prohibit the transfer of qualification from one organization to another. Therefore, each organization (company) must qualify the welding procedures and the welders employed by that company. This is based on the premise that each company is responsible for its welding and it is therefore, incumbent on the company to qualify their welding procedures and welders. For those welding codes that do permit transfer of qualification, the company must obtain actual qualification test documentation to support the transfer of qualification.

Identification of Welding Procedure to Weld Joint

The welding procedure used in making a weld must be retrievable at a future time. To make provision of this, weld inspection reports (normally completed by the QA/QC Technician) identify the weld joint number and the number of the welding procedure specification that was used in making the weld. As described previously in this module, the welding procedure specification in turn references the procedure qualification record. These documents provide objective evidence that a qualified welding procedure was used.

Identification of Welder to Weld Joint

One of two methods may be used to identify the welder to each weld joint. First, uniquely serialized stamps may be issued to each qualified welder. The welder stamps on or adjacent to each of his or her welds. Secondly, the weld inspection report may identify the weld joint and the

welder by name or number. In either method, all welders making a given weld must be identified.

To assist in assuring assignment of only qualified welders, most welding department managers maintain a folder or logbook for each welder. The folder or logbook contains or references for each welder the welder qualification records and times that welders performed welding. Such documentation enables the manager or lead person to quickly determine who is qualified for what and whether such qualification has been maintained through production welding.

EXERCISE

The following exercises should be completed as a means of reinforcing the concepts presented in this module.

1. Referring to the text and Table 28-5-5 or Table 28-5-6 as appropriate, determine if requalification is necessary for each of the following conditions. Explain response.
   a. A welder is qualified in the 6G position for a metal inert gas welding procedure. Would the welder need to be requalified for the 2G position for a tungsten inert gas welding procedure if all other essential variables remained the same?
   b. A shielded metal arc welding procedure is qualified. Would another shielded metal arc welding procedure need to be qualified by welding a test piece if it differed from the qualified procedure only as follows: change in current from 80 amps to 75 amps, change from flat to horizontal position and change from V groove to U groove?

c. A welder makes a procedure qualification test piece for a submerged arc welding procedure. The test results are satisfactory and the procedure is qualified. Would the welder be required to weld another test piece to become qualified for this procedure?

d. A qualified metal inert gas welding procedure is revised to change the arc transfer mode from spray arc to globular arc. Is requalification of the procedure required?

e. A qualified oxyacetylene welding procedure is revised to change from a neutral flame to a carburizing flame. Is requalification of the procedure required?

f. A qualified tungsten inert gas welding procedure is revised to change gas flow from 15 to 12 ft^3/hr, current from 45 to 42 amps, voltage from 12 to 10 volts and bare spooled wire to bare straight rod. Is requalification of the procedure required?

2. The following statements summarize the major points of this module. Place a check by each point as you recall it.

___ The specific number of qualification test pieces and the number and type of test specimens to be cut from each piece are specified by the governing welding code.

___ The three types of mechanical tests are tension, bend and impact.

___ Procedure qualification test pieces are normally subjected to tension and bend tests.

___ Impact tests are performed when the specification for the base material requires impact testing.

___ For procedure qualification, two tension and four bend tests are normally required.

___ Tension tests determine the strength of the weld. Bend tests determine the soundness and ductility of the weld. Impact tests determine the toughness of the weld.

___ Tension tests are not required for welder qualification because qualification of the procedure determined weld strength and the bend tests (or radiography) will indicate welder induced defects.

___ For side bend tests, one or the two cut surfaces becomes the convex surfaces after testing.

___ For face bend tests, the surface of widest weld width becomes the convex surface after testing.

___ For root bend tests, the surface of the narrowest weld width becomes the convex surface after testing.

3. Perform the three projects outlined in the PROCEDURES section of this Module. These are:
   a. Research the qualification requirements for a specific welding project
   b. Go on a tour of a welding qualification shop.
   c. Review administrative procedures for qualifying welders.

MATERIALS

The following materials are required to support this module:

1. ASME Boiler and Pressure Vessel Code, Section IX, Welding Qualifications (Reference copy)

2. AWS Structural Welding Code, AWS D1.1 (Reference Copy)
3. Industry administrative procedure for qualifying welding procedures and welders

PROCEDURES

1. Research a project to determine specific qualification requirements for a given welding process. Given information from the instructor should include title of welding code, name of welding process, values for essential and nonessential variables, and whether qualification requirements for procedure, welder, or both are to be determined. The given information could be an actual welding procedure specification obtained from a welder training program or from industry.
2. Go on a guided tour of a welding qualification shop. Complete Data Table 28-5-1 "Tour of Welding Qualification Shop" either during or after the tour. Discuss completed forms in class.
3. Review industry administrative procedures for qualifying welders and welding procedures against the applicable welding code. Obtain from the instructor copies of the administrative procedures and the applicable welding code. Identify key procedural controls and state if the procedure complies with the welding code.

DATA TABLE

Data Table 28-5-1
TOUR OF WELDING QUALIFICATION SHOP

As you go through the welding qualification shop, observe as many of the items on this data table as possible. Answer the questions or fill in the information that is requested.

1. Welding Process (check one)

___ oxyacetylene	___ metal inert gas
___ shielded metal arc	___ submerged arc
___ tungsten inert gas	___ other (specify)

2. Qualification is for procedure/welder (circle one)

3. base metal type_____
   joint design_____
   backing_____
   position_____
   current_____ AC _____ DC _____ Straight _____
   ___ Reversed _____
   voltage_____
   shielding_____
   filler material_____
   consumable insert_____ Yes _____ No _____

4. Test Specimens
   Sketch the test piece and indicate from where each specimen was obtained. Label each specimen by type of test.

5. Post Weld Heat Treatment

Used_____Yes _____No

Temperature range _____

All tests done after heat treatment_____Yes

_____No

6. Mechanial Tests

Check all that are applicable.

___ tensions ___ hardness

___ root bend ___ face bend

___ side bend ___ impact

Tensile Test

2% offset method_____Yes _____ Not Used

Tensile strength_____

Acceptable _____Yes _____ No

Hardness Test

Type _____

Value _____

Acceptable _____ Yes _____ No

Impact Test

Type _____

Acceptable _____ Yes _____ No

7. Chemical Test

Used _____ Yes _____ No

Type _____

Acceptable _____Yes _____ No

8. Radiography

Used _____ Yes _____ No

Indications _____

Acceptable _____ Yes _____ No

REFERENCE MATERIALS

ASME, Boiler and Pressure Vessel Code, Sections III and IX, 1979, American Society of Mechanical Engineers

AWS, Structural Welding Code, AWS D1.1, American Welding Society

AWS, Reinforcing Steel Welding Code, D12.1, American Welding Society

Match the code with its application

	Codes	Applications
1. ___	ASME Boiler and Pressure Code	a. welding of rebar in concrete
2. ___	AWS Structural Welding Code	b. welding of mobile vehicle frames
3. ___	AWS Reinforcing Steel Welding Code	c. welding of construction steel beams
		d. welding of safety related piping systems

State the purpose for qualifying:

4. welding procedure specifications
5. welders
6. Describe the method used for qualifying welding procedure specifications and welders.

State the purpose of the following documents:

7. welding procedure specification
8. procedure qualification record
9. welder qualification record
10. A radiography test report identifies that a weld made by a WPS 302 is acceptable. Describe how it can be determined if a qualified procedure was used to make the weld.
11. True or False (circle correct response):
    The number of welding procedure specifications always equals the number of procedure qualification records.
12. Give the basis for your answer to question 11.

13. Five features of each qualification test piece are typically controlled by requirements of the governing welding code. Name five features.

a.

b.

c.

d.

e.

Indicate whether statements 14 through 20 are true or false.

14. ____ When a welding procedure specification for fillet welding is to be qualified, the qualification test piece should be a fillet weld.

15. ____ If the only difference among three welding procedure specifications is the material type but all three materials types are of the same "P" number, only one qualification test piece is required.

16. ____ A qualification test piece of one inch thickness is suitable for qualification of welds one inch and less in thickness.

17. ____ A welder who qualifies in the horizontal position automatically qualifies for the flat position.

18. ____ Preheating need not be used in welding procedure specification qualification.

19. ____ Tests on the qualification test piece for qualification of a welding procedure specification are conducted after heat treatment of the welded test piece.

20. ____ An essential variable is a welding parameter that requires requalification of the procedure when it is changed beyond limits.

21. Briefly describe the responsibilities of the QA/QC Technician with respect to qualifications of welding procedures.

22. Describe how to determine if a given welding procedure specification is in fact qualified.

23. If the specific person is known who made a given field weld, describe how to determine if the welder is qualified for that weld. Include significance of welding process and calendar date.

24. Even though the welding procedure specification stipulates a maximum interpass temperature, welding of the procedure qualification test piece can omit control of interpass temperature. Give the rationale for such an omission.

25. Name three types of mechanical tests used in welding procedure qualifications and state the purpose of each.
a.

b.

c.

26. Describe the physical configuration of the weld in each of the following bend specimens after bending.

a. side bend:

b. face bend:

c. root bend: